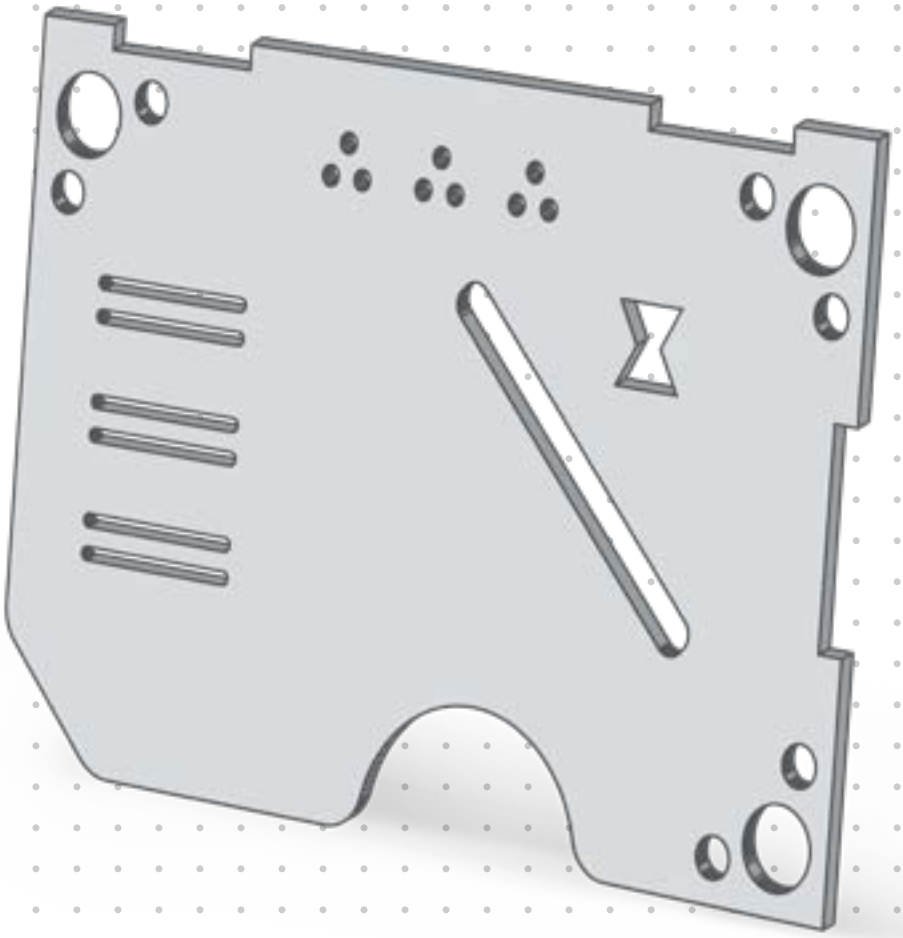
CoorsTek

Thick-Film Ceramic Substrates

Design Guide



The World's Leading OEMs Trust CoorsTek for Superior Results.

As a leading global manufacture of technical ceramics, CoorsTek has the scale, selection of materials, and capabilities to ensure on-time delivery, superior component fit and function, and optimal product life to keep our customers on the road to next-generation technology. CoorsTek has a highly qualified staff to assist with material selection and product design.

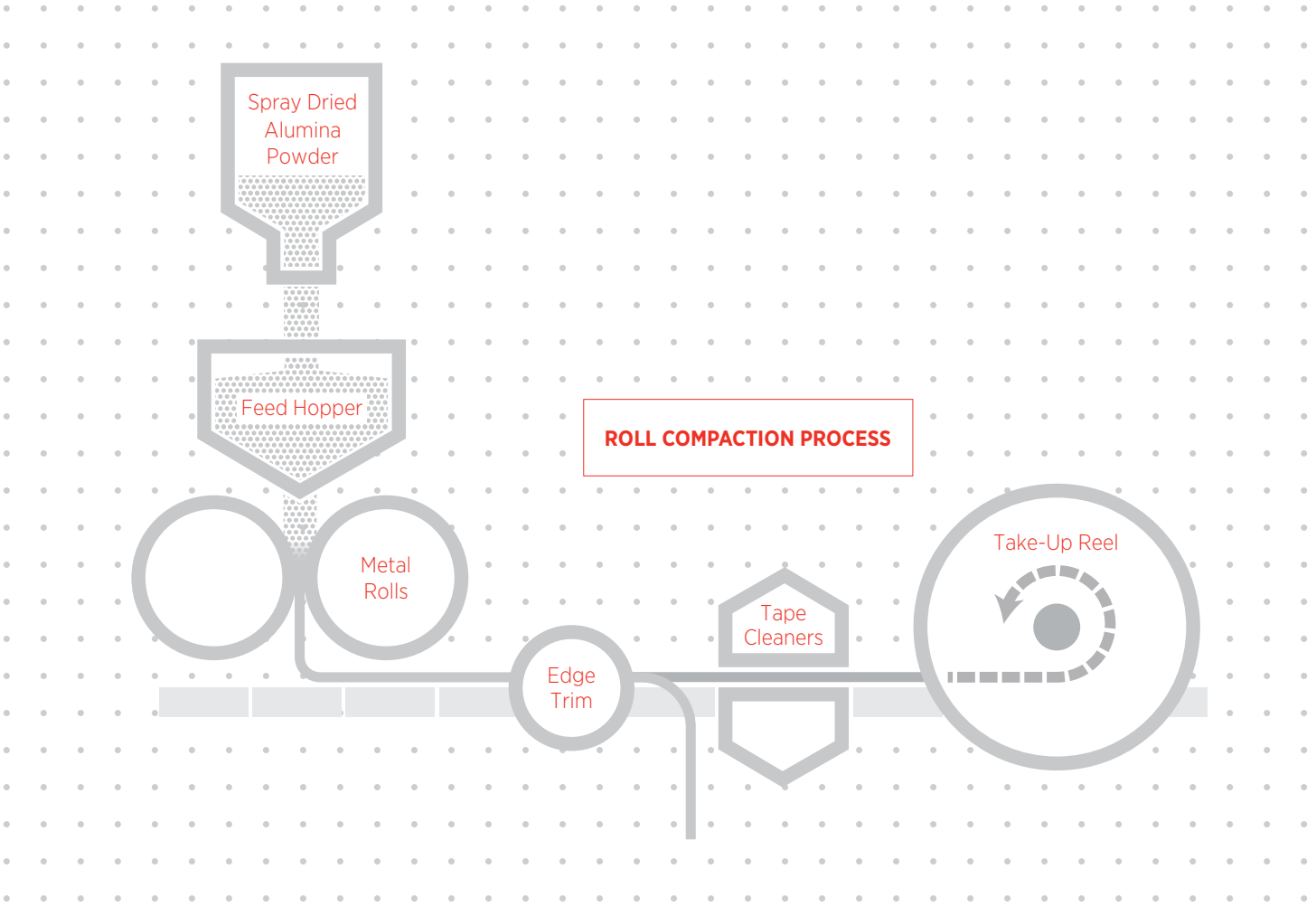
Scope and Intent

This publication is designed to provide engineers with design guidelines, material property information, inspection methods, and quality standards for CoorsTek thick-film alumina substrates. These guidelines will aid in optimizing substrate design and material selection in order to meet technical requirements while controlling cost.

If a substrate design does not comply with these guidelines, CoorsTek may still be able to offer options to specific design requirements. It is our practice to indicate exceptions to customer prints and specifications should they differ from these guidelines, for the purpose of offering alternatives and possible cost reduction.

Technology Overview

Roll compaction is a method of fabricating continuous thin sheets of ceramic materials by compacting flowable ceramic powders in a rolling mill. This fabrication technology allows parts to be manufactured to precise dimensional specifications, yields two identical working surfaces, and tighter thickness control. CoorsTek roll compaction substrate technology incorporates three basic steps: spray dried powder preparation, tape fabrication by roll compaction, and sintering.



As-Fired Substrates Design Guidelines

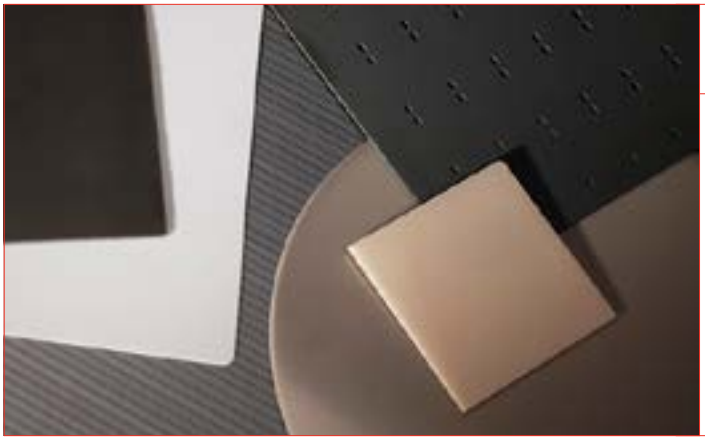
The following design standards represent factors to be considered ensuring optimal substrate design and material selection. Material samples are available upon request so that the design or process engineer can determine, by proof test, the product specifications best suited for intended applications.

Materials

ADS-96R

Thick Film Substrates

ADS-96R Thick-Film substrates are engineered to minimize as-fired resistor variations and maximize aged adhesion values. Superior resistor stability is achieved by controlling the substrates' effects on the temperature coefficient of resistance. ADS-96R is particularly well suited for small-geometry, high-resistor-value circuitry.



ADOS-90R

Opaque Substrates

ADOS-90R (opaque) is the alumina substrate material of choice for light-sensitive semiconductor device applications.

ADS-995R

Mid-Film™ Substrates

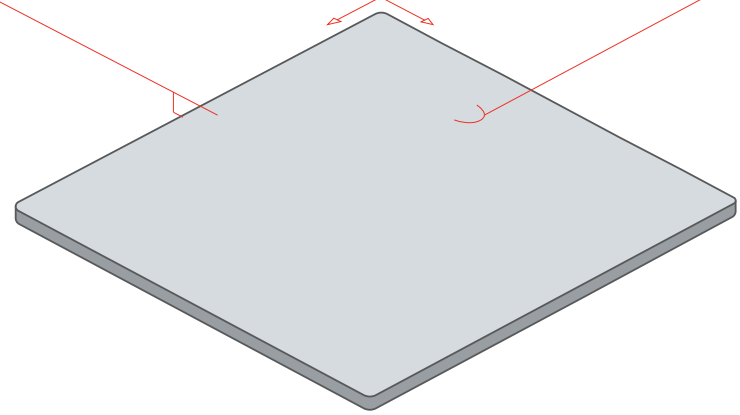
ADS-995R Mid-Film™ substrates are compatible with etchable ink and photo-formed systems, Mid-Film substrates have higher flexural strength, higher thermal conductivity, higher dielectric constant with lower loss.

As-Fired Dimensional & Design Criteria

Thickness Tolerances	
Standard	± 10% NLT ± 0.002″ (± 0.0508 mm)
Applies to thicknesses from 0.010″ (0.254 mm) to 0.125″ (3.18 mm)	

Length/Width Tolerances	
Standard	± 1½ % NLT ± 0.010″ (±0.254 mm)
Premium	± 1% NLT ± 0.004″ (± 0.102 mm)

Camber Tolerances	
Standard	≤ 0.003 in./in. (≤ 0.003 mm/mm)
Premium	≤ 0.002 in./in. (≤ 0.002 mm/mm)



Tooled Corner Radius
Minimum 0.125″ (3.175 mm) Radius required.

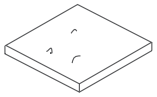
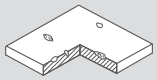
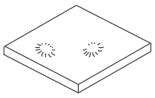
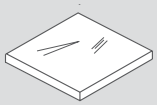
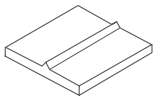
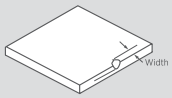
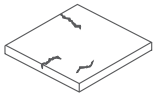
Thicknesses

CoorsTek offers thicknesses from 0.015″ (0.381 mm) to 0.100″ (2.54 mm). The most economical thickness range is 0.025″ (0.635 mm) to 0.040″ (1.016 mm).

Common form factors are for ADS-96R only. Other materials may have specific form factor constraints.

Common Sizes	
4.5″ x 4.5″	(114.3mm x 114.3mm)
4.5″ x 6.5″	(114.3mm x 165.2mm)
5.5″ x 6.5″	(139.7mm x 165.2mm)

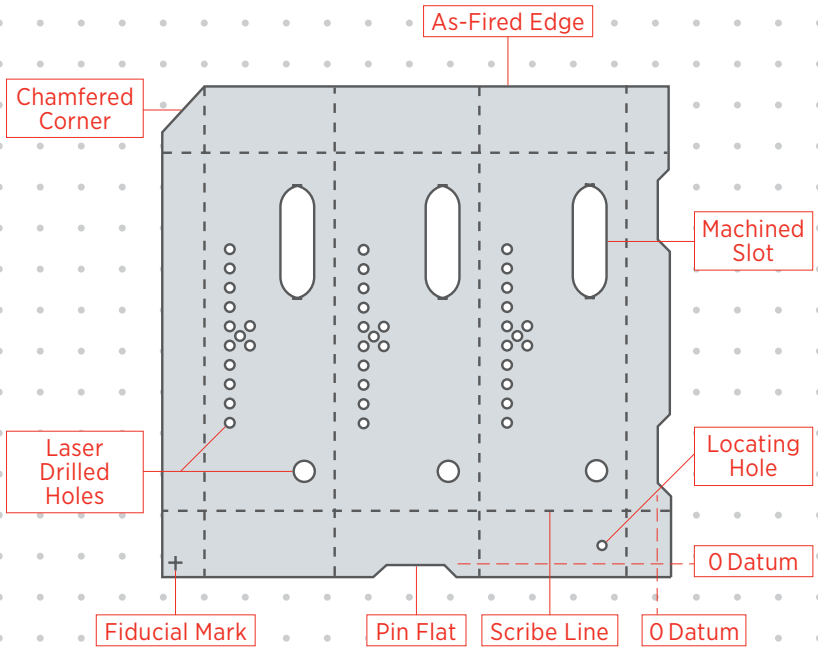
Surface Imperfection Criteria (substrates with surface area > 35 in² inspected with unaided eye in ambient light)

Surface Imperfections		Acceptance Criteria	
		Surface Area < 35 in²	Surface Area > 35 in²
Burrs/Excess Body Fragment of excess material or foreign particle adhering to the surface		None > 0.001" (0.025 mm) High	None > 0.020" (0.508 mm) High
Pits and Holes A deep void in the surface		None > 0.030" (0.762 mm) Diameter	None > 0.050" (1.27 mm) Diameter
Blisters Bubble or gaseous inclusion at the surface which, if broken, could form a pit, pock, or hole		None > 0.001" (0.025 mm) High	None > 0.010" (0.254 mm) High
Scratches Relatively long, narrow, shallow groove or cut in the surface		None > 0.0007" (0.017 mm) Deep	—
Bumps or Ridges Protrusions on the surface		None > 0.001" (0.025 mm) High	None > 0.020" (0.508 mm) High
Chips Open: Material broken off along an edge or corner Closed: Material has not broken off or separated		Print Face = None > 0.030" (0.762 mm) x 50% of thickness Waste Border = unlimited length x 100% of thickness	None > 0.050" (1.27mm) x 50% of thickness x unlimited length
Cracks A visible line or fracture		None	None when inspected with unaided eye at ambient light.

Laser Services

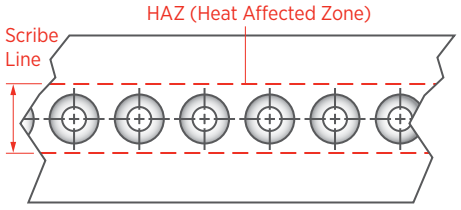
The following are designed to provide engineers with design guidelines, inspection methods, and quality standards for laser machining/profiling, drilling, and scribing of CoorsTek thick-film alumina substrates. These guidelines will aid in optimizing lasered substrate design in order to meet your technical requirements cost-effectively. The illustration below depicts some of our laser capabilities.

If a lasered substrate design does not comply with these guidelines, we can still offer options to your specific design requirements. CoorsTek will indicate exceptions to customer drawings and specifications should they differ from these guidelines, for the purpose of offering alternatives and possible cost reduction. We offer services in design consultation, rapid prototyping, and expedited deliveries for laser scribing, machining, and annealing. Lapping and Grinding services are available upon request.

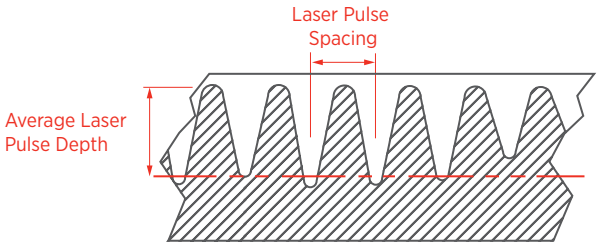


Laser Scribing

CoorsTek offers special differential scribing to enhance preferential singulation. By varying the laser pulse spacing and depth in the (x) and (y) scribe directions, the sequence of singulation may be controlled more precisely. Enhanced laser scribing helps to prevent hooking, chipping, and premature breakage, which improves process yields. The following illustrations and tables show typical scribe line configurations and tolerances.



Top View of Laser Scribed Substrate



Side View of Laser Scribed Substrate

CoorsTek Recommended Laser Scribing Parameters.

These parameters can be adjusted to specific customer requirements.

LASER SCRIBED TOLERANCES

Nominal Substrate Thickness		Resultant Segment Tolerance From Two Broken Edges		Laser Scribed EdgeTo First Scribe Line	
0.015″	0.381 mm	+0.006″ -0.002″	+0.15 mm -0.05 mm	+0.004″ -0.002″	+0.10 mm -0.05 mm
0.020″	0.508 mm	+0.006″ -0.002″	+0.15 mm -0.05 mm	+0.005″ -0.002″	+0.13 mm -0.05 mm
0.025″	0.635 mm	+0.006″ -0.002″	+0.15 mm -0.05 mm	+0.005″ -0.002″	+0.13 mm -0.05 mm
0.030″	0.762 mm	+0.008″ -0.002″	+0.20 mm -0.05 mm	+0.006″ -0.002″	+0.15 mm -0.05 mm
0.035″	0.889 mm	+0.008″ -0.002″	+0.20 mm -0.05 mm	+0.007″ -0.002″	+0.18 mm -0.05 mm
0.040″	1.02 mm	+0.008″ -0.002″	+0.20 mm -0.05 mm	+0.007″ -0.002″	+0.18 mm -0.05 mm
0.050″	1.27 mm	+0.008″ -0.002″	+0.20 mm -0.05 mm	+0.007″ -0.002″	+0.18 mm -0.05 mm
0.060″	1.52 mm	+0.014″ -0.002″	+0.36 mm -0.05 mm	+0.010″ -0.002″	+0.25 mm -0.05 mm
0.080″	2.03 mm	+0.020″ -0.004″	+0.51 mm -0.10 mm	+0.012″ -0.003″	+0.30 mm -0.08 mm
0.100″	2.54 mm	+0.025″ -0.004″	+0.64 mm -0.10 mm	+0.014″ -0.003″	+0.36 mm -0.08 mm

Notes:
1. Laser machined edges to first scribe line tolerance is ± 0.002″ (± 0.051 mm) for all substrate thicknesses.
2. Scribe line to scribe line tolerance prior to breaking is ± 0.002″ (± 0.051 mm).
3. Perpendicularity and parallelism of scribe lines and/or scribed and broken edges will not exceed 0.0005 in/in (0.0005 mm/mm) when measured at the average laser pulse centers.

STANDARD LASER SCRIBED PULSE DEPTH & SPACING - NON ANNEALED

Substrate Thickness Range		Average Pulse Spacing		Average Pulse Depth	
0.0150″ - 0.017″	0.317 mm - 0.431 mm	0.005″ ±0.0005″	0.1270 mm ±0.0127 mm	0.006″ ±0.003″	0.1524 mm ±0.0762 mm
0.0175″ - 0.022″	0.444 mm - 0.558 mm	0.006″ ±0.0005″	0.1524 mm ±0.0127 mm	0.009″ ±0.003″	0.2286 mm ±0.0762 mm
0.0225″ - 0.027″	0.571 mm - 0.685 mm	0.006″ ±0.0005″	0.1524 mm ±0.0127 mm	0.012″ ±0.003″	0.3048 mm ±0.0762 mm
0.0275″ - 0.032″	0.698 mm - 0.812 mm	0.006″ ±0.0005″	0.1524 mm ±0.0127 mm	0.013″ ±0.003″	0.3302 mm ±0.0762 mm
0.0325″ - 0.037″	0.825 mm - 0.939 mm	0.006″ ±0.0005″	0.1524 mm ±0.0127 mm	0.015″ ±0.003″	0.3810 mm ±0.0762 mm
0.0375″ - 0.045″	0.952 mm - 1.143 mm	0.006″ ±0.0005″	0.1524 mm ±0.0127 mm	0.018″ ±0.003″	0.4572 mm ±0.0762 mm
0.0455″ - 0.055″	1.155 mm - 1.397 mm	0.007″ ±0.001″	0.1778 mm ±0.0254 mm	0.024″ ±0.005″	0.6096 mm ±0.127 mm
0.0555″ - 0.065″	1.409 mm - 1.651 mm	0.007″ ±0.001″	0.1778 mm ±0.0254 mm	0.030″ ±0.005″	0.7620 mm ±0.127 mm
0.0655″ - 0.075″	1.663 mm - 1.905 mm	0.008″ ±0.001″	0.2032 mm ±0.0254 mm	0.035″ ±0.005″	0.8890 mm ±0.127 mm
0.0755″ - 0.085″	1.917 mm - 2.159 mm	0.008″ ±0.001″	0.2032 mm ±0.0254 mm	0.040″ ±0.005″	1.016 mm ±0.127 mm
0.0855″ - 0.095″	2.171 mm - 2.413 mm	0.009″ ±0.001″	0.2286 mm ±0.0254 mm	0.045″ ±0.005″	1.143 mm ±0.127 mm
0.0955″ - 0.100″	2.425 mm - 2.540 mm	0.009″ ±0.001″	0.2286 mm ±0.0254 mm	0.050″ ±0.005″	1.270 mm ±0.127 mm

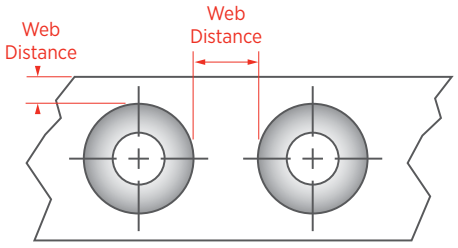
STANDARD LASER SCRIBED PULSE DEPTH & SPACING - ANNEALED

Substrate Thickness Range		Average Pulse Spacing		Average Pulse Depth	
0.0150″ - 0.017″	0.317 mm - 0.431 mm	0.004″ ±0.0005″	0.1016 mm ±0.0127 mm	0.007″ ±0.003″	0.1778 mm ±0.0762 mm
0.0175″ - 0.022″	0.444 mm - 0.558 mm	0.005″ ±0.0005″	0.1270 mm ±0.0127 mm	0.010″ ±0.003″	0.254 mm ±0.0762 mm
0.0225″ - 0.027″	0.571 mm - 0.685 mm	0.005″ ±0.0005″	0.1270 mm ±0.0127 mm	0.013″ ±0.003″	0.3302 mm ±0.0762 mm
0.0275″ - 0.032″	0.698 mm - 0.812 mm	0.005″ ±0.0005″	0.1270 mm ±0.0127 mm	0.014″ ±0.003″	0.3556 mm ±0.0762 mm
0.0325″ - 0.037″	0.825 mm - 0.939 mm	0.005″ ±0.0005″	0.1270 mm ±0.0127 mm	0.016″ ±0.003″	0.4064 mm ±0.0762 mm
0.0375″ - 0.045″	0.952 mm - 1.143 mm	0.005″ ±0.0005″	0.1270 mm ±0.0127 mm	0.019″ ±0.003″	0.4826 mm ±0.0762 mm
0.0455″ - 0.055″	1.155 mm - 1.397 mm	0.006″ ±0.0005″	0.1524 mm ±0.0127 mm	0.025″ ±0.005″	0.635 mm ±0.127 mm
0.0555″ - 0.065″	1.409 mm - 1.651 mm	0.0065″ ±0.0005″	0.1651 mm ±0.0127 mm	0.033″ ±0.005″	0.828 mm ±0.127 mm
0.0655″ - 0.075″	1.663 mm - 1.905 mm	0.0075″ ±0.0005″	0.1905 mm ±0.0127 mm	0.038″ ±0.005″	0.965 mm ±0.127 mm
0.0755″ - 0.085″	1.917 mm - 2.159 mm	0.0075″ ±0.0005″	0.1905 mm ±0.0127 mm	0.043″ ±0.005″	1.092 mm ±0.127 mm
0.0855″ - 0.095″	2.171 mm - 2.413 mm	0.009″ ±0.001″	0.2286 mm ±0.0254 mm	0.045″ ±0.005″	1.143 mm ±0.127 mm
0.0955″ - 0.100″	2.425 mm - 2.540 mm	0.009″ ±0.001″	0.2286 mm ±0.0254 mm	0.050″ ±0.005″	1.127 mm ±0.127 mm

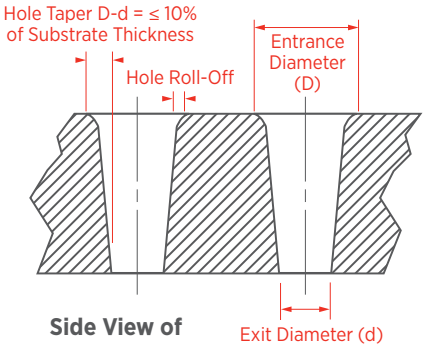
Laser Services (continued)

Laser Machining

Coorstek offers machining services for precise hole location, edge definition, and to produce custom shapes and sizes. The following illustrations and tables show typical configurations, design guidelines, and tolerances.

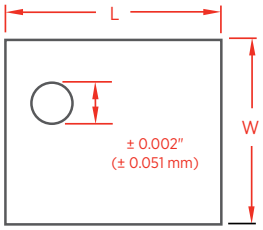


Top View of Laser Hole



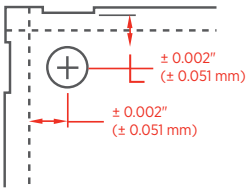
Side View of Laser Hole

Laser Machining Specifications Guide

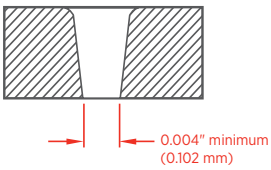


1. Length and Width
± 0.002″ (±0.051 mm)

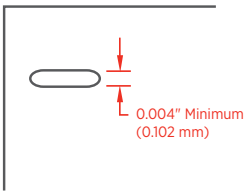
2. Hole Diameter
± 0.002″ (± 0.051 mm)



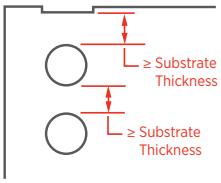
3. Hole Location: ± 0.002″ (± 0.051 mm)
- From any machined area to hole centerline
- From center of scribe lines to hole centerline



4. Minimum Hole Diameter
- Typically = 0.004″ (0.102 mm)

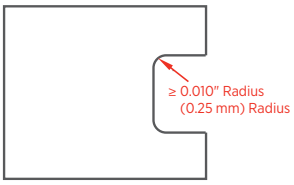


5. Minimum Slot Width
- Typically 0.004″ (0.102 mm)



6. Minimum Web Thickness
- Hole edge to another edge–substrate thickness
- Between adjacent holes–substrate thickness

Note: Thinner Materials are more forgiving in this area



7. Corner Radius
- 0.010″ (0.254 mm) Radius

Note: Specify internal corner radii rather than sharp corners (90°) to avoid microcracking and chipping.

Tolerances

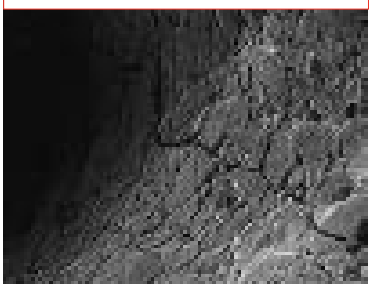
These specifications are based on the application of statistical process control methods to determine multibeam equipment capability to a Cpk of ≥ 1.33.

Annealing

Annealing treatments are also available. CoorsTek offers annealing treatments to modify the microstructure of the heat affected zone (HAZ) in a laser drilled hole (reference photos to right) and/or to relieve any residual substrate stresses. The annealed microstructure provides an enhanced surface for metallization, thus improving via metal adhesion. The annealing process also increases the breaking force required for singulation of laser scribed substrates. Laser scribing parameters will be adjusted to result in desired singulation (as shown in the table on page 7).

Unannealed Laser Pulse

Annealed Laser Pulse

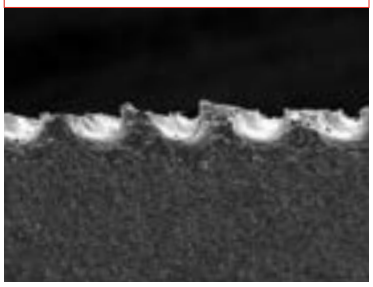


Scanning electron photomicrographs of ADS-96R (1,000x and 30° tilt)

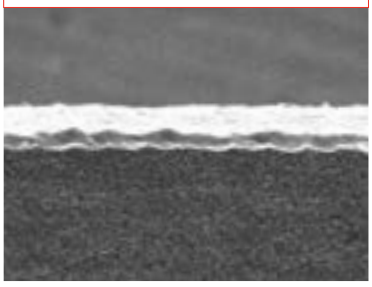
Lasered Edge Treatments

CoorsTek offers a variety of edge finishing treatments: laser scribed, laser scribed and brushed, SilkEdge™ substrates, SmoothEdge™ substrates, and laser-machined substrates. Contact your CoorsTek sales representative for availability of specific edge finishing treatments. Note: Laser edge treatment availability is geometry dependent.

Laser Scribed Edge

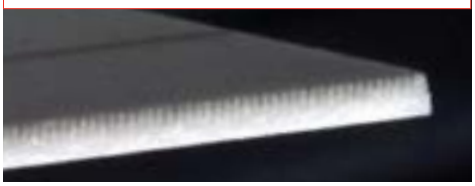


Laser Machined Edge



Scanning electron photomicrographs of ADS-96R (100x)

Laser Scribed Edge



SmoothEdge™ Substrates

SilkEdge™ Substrates

Quality Assurance

CoorsTek is committed to providing the service and quality customers have come to expect. CoorsTek is ISO-9001 and IATF 16949 Certified to ensure product quality and traceability. Our quality system is built around Six Sigma Quality and Lean Manufacturing techniques.

Quality is achieved by utilizing our customer's expectations to select target values and minimize variation around those values. Customer satisfaction is our highest goal.

Inspection

Requirement

CoorsTek uses industry standards for our in-process and final inspections. The following lists our typical requirements.

INSPECTION TABLE		
Feature	**Typical Inspection Level**	**Measurement Device**
External Sizes	Sample Plan C=0 AQL .65	Calipers, Micrometers
Internal Feature Location and Size	Sample Plan C=0, AQL 10	Optical Measurement Equipment, Pin Gages
Dye Check	Sample Plan C=0 AQL .65	Dye Penetrant
Camber (As-Fired/Lapped), Final Inspection	Sample Plan C=0 AQL .65	Camber Bar (See Methods Section)
Camber (As-Fired/Lapped), In-Process	100%	
Visual, Final Inspection	Sample Plan C=0 AQL .65	See Methods Section
Visual, In Process	100%	
All Other Specifications	Sample Plan C=0 AQL .65	

Methods

Visual Inspection Procedures: As-Fired and Lasered: Visual only using low angle light with unaided eye; except as noted in large area specification.

Length/Width: Length and width dimensions are inspected using calipers or optical measurement equipment as dictated by tolerances.

Thickness: Thickness is measured using optical and/or mechanical measurement as required by the process.

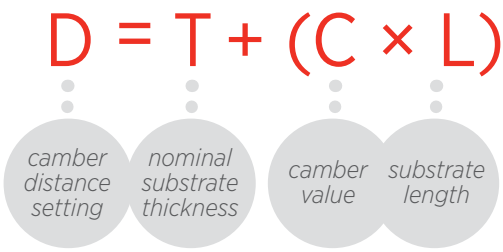
Surface Finish: Surface finish is measured on a sample basis using contact methods. Published values represent the substrate's typical or average surface finish. CLA (Centerline Average), Ra (Roughness average) and AA (Arithmetic Average) are equivalent terms.

Surface Porosity: Dye penetrant is used to determine surface porosity.

VERIFICATION OF SURFACE IMPERFECTIONS	
Surface Imperfection	**Verification Method**
Bumps or Ridges	Contact Micrometer
Pits, Holes, Chips and Surface Marks	Low angle light, unaided eye
Cracks	Dye penetrant

Camber Test Method: CoorsTek substrates are 100% inspected for camber using two ground, parallel plates spaced at a fixed distance by the following formula:

Camber distance setting, D = T + (C x L), where:
T = nominal substrate thickness
C = camber (inches per inch or mm per mm)
L = substrate length or longest outside dimension



ENGLISH EXAMPLE:

For a 4.0″ x 3.5″ x 0.025″ substrate:
Nominal substrate thickness, T = 0.025″
Camber, C = 0.003″ per inch
Longest outside dimension, L = 4.0″
Camber distance setting,
D = 0.025″ + (0.003″ per inch x 4.0″) = 0.037″

METRIC EXAMPLE:

For a 101.6 mm x 88.9 mm x 0.635 mm substrate:
Nominal substrate thickness, T = 0.635 mm
Camber, C = 0.003 mm per mm
Longest outside dimension, L = 101.6 mm
Camber distance setting,
D = 0.635 mm + (0.003 mm per mm x 101.6 mm) = 0.9398 mm

To inspect for camber, parallel plates are set with a gap equal to the D value determined in the formula. Substrates that pass through the gap under their own weight are acceptable. Camber bar sets are available for purchase from CoorsTek.

Hole Sizes and Shapes: Hole diameters and shapes are verified using computer-enhanced optical measuring with top or back light equipment or pin gauges. Method of hole verification will be chosen for best correlation on hole size between CoorsTek and customer.

Hole Locations: CoorsTek standard procedure for inspection of hole locations is computer-enhanced optical measuring equipment on the entry side using top light.

Scribe Lines:
Before Break: Scribe line locations are inspected using computer-enhanced optical measuring equipment.

After Break: The part segments are inspected by contact measurement.

Chips: Inspection for chips is done under a high-intensity, low-angle light using the unaided eye.

Part Features: Location and size of part features are inspected with computer-enhanced optical measuring equipment.

Pulse Depth: Average laser pulse depth is inspected on a substrate cross section using enhanced optical methods. The average is determined over a minimum of 10 adjacent pulses.

Pulse Spacing: Average laser pulse spacing is inspected using enhanced optical methods. The average is determined over 11 adjacent pulses.

Slag Height: Slag height is inspected by contact measurement.

Cracks: Inspection for cracks is performed using a dye penetrant or other appropriate techniques.

Thick-Film Ceramic Substrates Design Guide

Typical Material Properties

Characteristic		Unit	Test Method	ADOS-90R	ADS-96R	ADS-995R MidFilm™
Alumina Content		Weight %	ASTM D2442	91	96	99.5
Color (Color is for reference only. Shades may vary.)		–	–	DARK BROWN	WHITE	IVORY
Density		g/cm^3 (lb/ft^3)	ASTM C373	3.72 (0.134)	3.72 (0.134)	3.9 (0.141)
Hardness–Rockwell		–	ASTM E18, R45N	78	82	84
Surface Finish – CLA (as-fired)		Microinches (Micrometers)	Contact Profilometer	45 (1.14)	35 (0.89)	35 (0.89)
Average Grain Size		Micrometers	ASTM E112 Abrams (Intercept Method)	5	4	2
Water Absorption		%	ASTM C373	NIL	NIL	NIL
Flexural Strength		Kpsi (MPa)	ASTM F394	53 (365)	58 (400)	64 (440)
Elastic Modulus		10^6 psi (GPa)	ASTM C623	45 (310)	48 (330)	55 (380)
Poisson's Ratio		–	ASTM C623	0.24	0.25	0.24
Coefficient of Linear Thermal Expansion	25° - 200° C 25° - 500° C 25° - 800° C 25° - 1000° C	10^{-6} / °C (10^{-6} / °F)	ASTM C372	6.4 (3.6) 7.3 (4.1) 8.0 (4.4) 8.4 (4.7)	6.4 (3.6) 7.2 (4.0) 7.9 (4.4) 8.2 (4.6)	6.4 (3.6) 7.2 (4.0) 7.6 (4.2) 8.0 (4.4)
Thermal Conductivity	20° C 100° C 400° C	W/m°K (Btu•in/ft^2•h•°F)	ASTM E1461	13 (90) 12 (83) 8 (56)	26 (180) 20 (139) 12 (83)	31 (215) 23 (160) -
Dielectric Strength (60 cycles AC avg. RMS)	0.025" thick 0.040" thick	Volts/mil (Kv/mm)	ASTM D149	540 (21.3) -	600 (23.6) 490 (19.3)	595 (23.4) -
Dielectric Constant (Relative Permittivity)	1MHz	@ 25° C	ASTM D150	10	9	10
Dissipation Factor (Loss Tangent)	1MHz	@ 25° C	ASTM D150	0.005	0.0004	0.0003
Loss Index (Loss Factor)	1MHz	@ 25° C	ASTM D150	0.05	0.004	0.003
Volume Resistivity	25° C 300° C	ohm-cm or ohm-cm^2/cm	ASTM D257	> 10^{14} 4 x 10^8	> 10^{14} 1.0 x 10^{12}	> 10^{13} > 10^9

This table illustrates typical properties only. Property values vary with methods of manufacture and form factor. Data contained herein is not to be construed as absolute and does not constitute a representation or warranty for which CoorsTek assumes legal responsibility. CoorsTek substrate materials listed above comply with the EU Directive on RoHS and with REACH. CoorsTek is a registered trademark of CoorsTek, Inc

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